PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Serial No.:	09/665,724	Applicant(s):	Joseph E. CLOUTIER et al.
Filed:	September 20, 2000	Conf. No.:	2665
Group:	2681	Examiner:	Toan D Nguyen

For: IMPROVED WIRELESS DATA TRANSMISSION USING TIME OUT CONTROL

Attorney Docket No.: 29250-000683/US

March 11, 2005

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401 Dulany Street
Alexandria, VA 22314
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DECLARATION UNDER 37 C.F.R. §1.131

Sir:

We, Joseph E. Cloutier, Tejaskumar R. Patel, James C. Stekas, and Tomas S. Yang, declare:

1. We are the joint inventors of all the originally filed claims of the above-identified patent application.

2. The application is currently assigned to Lucent Technologies Inc. as recorded September 20, 2000, REEL/FRAME: 011175/0291 .

3. Prior to September 15, 2000, we conceived a base station, communication device and method for improved wireless data transmission using time out control.

4. Prior to September 15, 2000, we had disclosed our invention to others within the Lucent Technologies Inc., and had submitted a written description of the invention to Lucent Technologies' legal department for preparation of a patent application. A copy of the submission (with dates redacted) is attached as Exhibit A.

5. The above-listed act occurred in the United States.

6. On September 20, 2000, the present application, U.S. Patent Application Serial No. 09/665,724, was filed with the United States Patent and Trademark Office.

7. We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Joseph E. Cloutier — Date: 3/9/05

Tejaskumar R. Patel — Date: 3/9/05

James C. Stekas — Date: 3/9/05

Tomas S. Yang — Date: 3/9/05

Attachments: Exhibit A

EXHIBIT A

Lucent Technologies
Bell Labs Innovations

Stephen M. Gurey
Intellectual Property

[redacted]

Re: Cloutier 4-4-1-1

Gary Yacura
Harness Dickey & Pierce, PLC

Gary,

As per your request.

Steve

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WIRELE^^ INVENTION SUBMISSI^N FORM

II CNM

Title of Invention:	TCP Timeout Prevention Algorithm for Wireless Systems
Name of inventors, telephone, address and business unit:	James C. Stekas WH x66622 Room 2A244 AMPS/PCS Joseph Cloutier WH x67871 Room 14A273 AMPS/PCS Tejaskumar Patel WH x85839 Room 2A240 AMPS/PCS Tomas Yang WH x66469 Room 14H205 AMPS/PCS
Name of principal person to work with attorney:	James C. Stekas
What problem does the invention solve or what purpose does it serve?	Internet applications using TCP/IP over on wireless links are particularly susceptible to momentary interruptions due to fading or channel congestion. In addition to stopping data transmission momentarily these interruptions can cause TCP receiver timeouts (RTO) reducing data throughput substantially. In many practical wireless internet applications RTOs are the principal obstacle achieving high data throughput. Our approach controls the flow of data between the wireless system and the Internet to minimize receiver timeouts.
Explain your solution. Attach any sketches, lab notebook entries, TMs, etc. which help describe and illustrate the solution:	Our solution to this problem is to detect patterns in traffic flow characteristic of a TCP transfer susceptible to a RTO and inject random delay into the data path. This causes variation in the round trip time between TCP receiver and transmitter that causes the receiver to increase its RTO threshold. (Memo provided)
Under what circumstances would it be economically advantageous for someone outside of Lucent to make, use or sell the invention?	Any IP network with dynamic throughput will suffer RTOs and benefit from this algorithm. This is the case for all 3G wireless systems (cdma2000, UMTS and WCDMA) due to channel variability from fading and dynamic capacity allocation to support multiple users.
How easily could Lucent detect, or suspect, that someone was making, using or selling the invention?	This could be easily detected by establishing a data call through a competitors system and measuring round trip delay statistics during an FTP file transfer.
How easily can the invention be designed around? In other words, how easily can another designer achieve the same functionality with a different design and for roughly the same costs?	Not easily. Other approaches are very difficult: 1. Improving the air interface through new standards, new radio hardware and new software. 2. Modifying TCP in existing systems (i.e. Windows, Unix, etc.)

Signature of Dept. Head of Principal Inventor
Print Name: JOSEPH A-TARALLO

[redacted]
Date

Francis O'Brien, Technology Director
Wireless Standards Development and Industry Relations

[redacted]
Date

WIRELE S INVENTOR INFORMA ION FORM

PLEASE NOTE THE FOLLOWING:

- A **separate** Wireless Inventor Information form needs to be completed by **each** inventor.
- Please **attach** all Wireless Inventor Information forms, any memos, sketches, lab notebook entries, etc. to the appropriate Wireless Invention Submission form (see next page).
- **Forward** the completed package to your respective Department Head for his/her signature. Your Department Head will forward the package to John Marinho for final approval.

QUESTIONS??? Please contact Barbera Armstrong at (973) 386-3957 or via e-mail at barmstrong@lucent.com.

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WIRELESS INVENTOR INFORMATION FORM

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WIRELESS INVENTOR INFORMATION FORM

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Lucent Technologies Bell Labs Innovations

Lucent Technologies Network Wireless Systems

subject: **TCP Receiver Timeout Control**

date: [redacted]
from: **Joseph Cloutier**
Tejas Patel
Jim Stekas
Tomas Yang

1. Introduction

Internet applications using TCP/IP over on wireless links are particularly susceptible to momentary interruptions due to fading or channel congestion. In addition to stopping data transmission momentarily these interruptions can cause TCP receiver timeouts (RTO) reducing data throughput substantially. Any IP network with dynamic throughput will suffer RTOs and benefit from this algorithm. This is the case for all 3G wireless systems (cdma2000, UMTS and WCDMA) due to channel variability from fading and dynamic capacity allocation to support multiple users.

In many practical wireless internet applications RTOs are the principal obstacle achieving high data throughput. Our approach controls the flow of data between the wireless system and the Internet to minimize receiver timeouts.

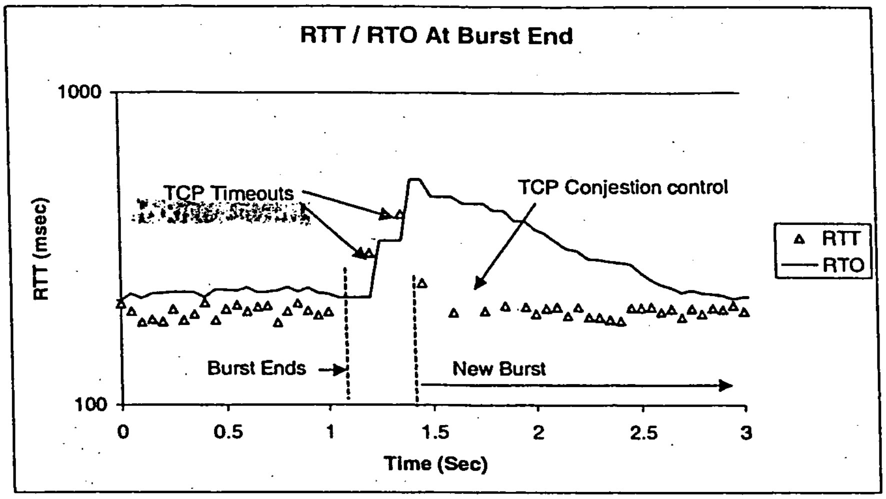
Out approach to Receiver Timeout Control is to detect patterns in traffic flow characteristic of a TCP transfer susceptible to a RTO and inject random delay into the data path. This causes variation in the round trip time between TCP receiver and transmitter that causes the receiver to increase its RTO threshold. (See Section 1.1)

1.1 TCP Receiver Timeout

A TCP receiver uses a timeout threshold (for a return ACK) that is a function of the round trip delay:

$$RTO = \bar{t}_{RT} + 4 \cdot \sqrt{\mathrm{var}(t_{RT})}$$

where RTO is the timeout threshold and t_{RT} is the round trip time. In a typical wired system network conditions don't change rapidly and t_{RT} is relatively stable. In a wireless system shadow fading or the low rate interval between bursts can cause very large delays.



The figure above is an example of what can happen in the interval between data bursts. During the high speed data burst (0-1sec) round-trip delay (RTT) is well clustered around 200ms and the receiver timeout (RTO) has adapted to this behavior. When the burst ends data flows at low speed causing a long RTT and a TCP timout. This causes TCP to enter a congestion control mode (slow-start) that dramatically reduces data flow.

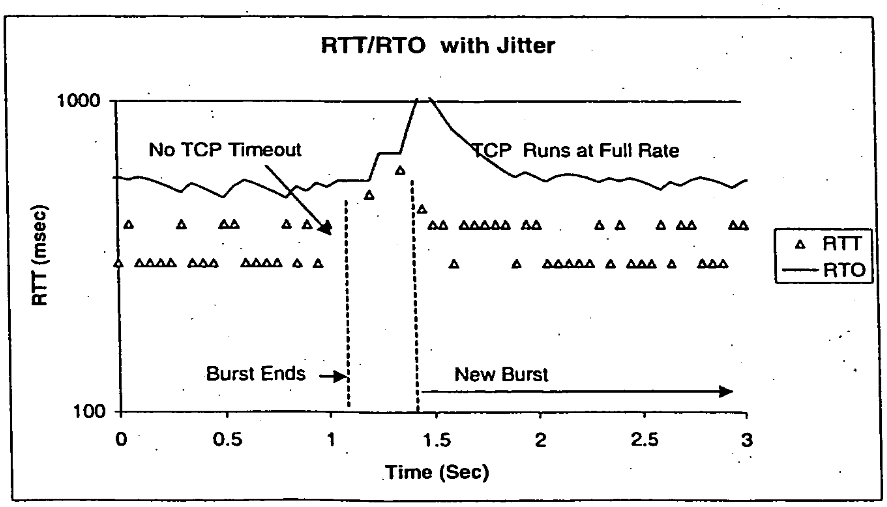
Adding random delay (jitter) will increase the mean and variance of the RTT. In the example below 100ms delay is added randomly to half the TCP ACK packets resulting in:

$$\Delta RTT = 50ms$$

$$\Delta \operatorname{var}(RTT) = (50ms)^2$$

$$\Delta RTO \Rightarrow 50ms + 4 \cdot 50ms = 250ms$$

The result is to increase the RTO margin by 200ms and prevent the end-of-burst timeouts as shown in the figure below.



2. General RTO Control Algorithm

2.1 Considerations for Optimal Performance

2.1.1 Optimal Jitter Distribution

Injecting jitter with bimodal statistics as in the above example is optimal since it maximizes the increase the RTT variance with the minimum increase in mean RTT. This generates a 4-fold increase in RTO margin for a given increase in mean delay.

2.1.2 When to Add Jitter

Additional jitter is most beneficial when traffic is over a single TCP socket - e.g. downloading a large FTP file. When multiple TCP sockets share the same physical channel contention between packets from different sockets will cause additional jitter, and if a TCP socket does suffer a time-out other sockets will utilize the capacity freed by congestion control and the physical channel will be fully utilized.

2.1.3 Where to Add Jitter

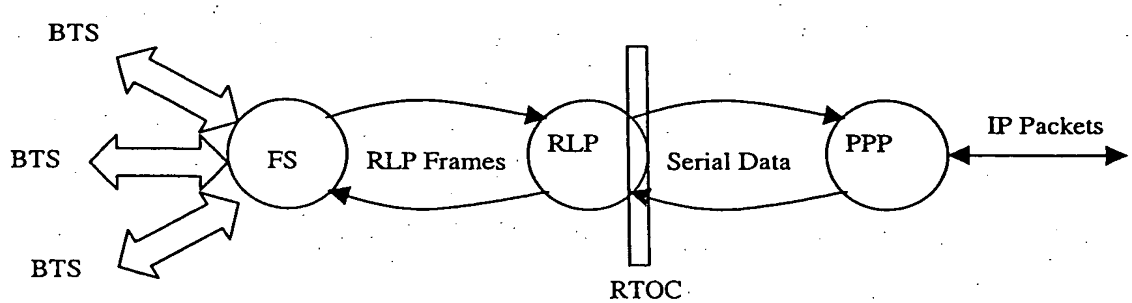
The optimal way to add jitter is to delay the ACKs in the TCP stream since these packets are small and require minimal buffer memory.

2.1.4 Non-TCP Aware Approach

The physical radio channel is a serial stream of data transported in a Radio Link Protocol (RLP) that provides a small probability of packet loss through the retransmission of errored data. Since the RLP layer has no visibility into TCP/IP packets the RTO Control Algorithm cannot use any information at the TCP and IP layers.

2.2 General RTO Control Algorithm Description

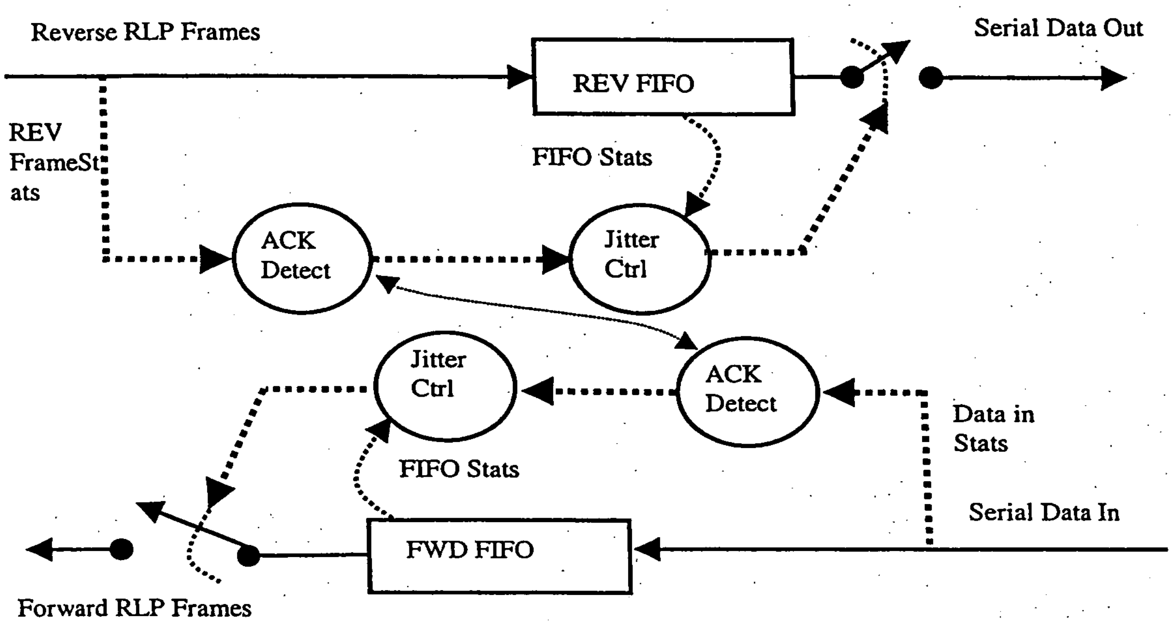
The RTO Control Algorithm (RTOC) is designed to operate at the interface between RLP and the IP network. In the IS2000 3G system (see below) this is the serial data stream of a PPP session serving a remote users connection to the Internet.



Although the above diagram is specific to IS2000, all 2G and 3G wireless data solutions are sufficiently simlar in architecture (at the RLP interface) that the approach will work on any of them.

2.2.1 Functional Block Diagram

The diagram below shows the general structure of the RTOC.

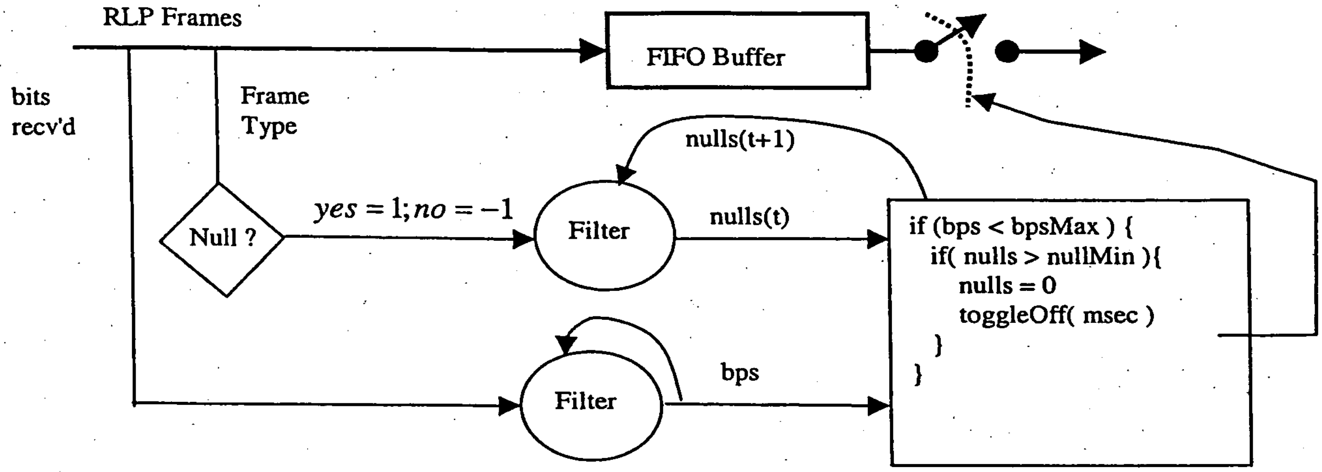


Critical functions are as follows:

- *ACK Detect* assesses if the link is in an "ACK" mode and jitter should be applied. Evidence of this includes low avarage rate data with long periods (~100ms) of no data. Statistics available for this assessment include average bit rate, null and data frame patterns, data "duty cycle", etc. (Knowledge that the link in the opposite direction is heavily loaded may also be a useful clue.)
- *Jitter Cntrl* toggles the flow of data to optimize the RTT variance within delay constraints and FIFO buffer size. This function would use FIFO size and age statistics to accomplish this.

2.3 Simple RTOC Implementation

Whatever the "optimum" algorithm RTOC may be, we have gotten very good results with the simple algorithm diagramed below.



To identify likely periods of "ACKing" a recursive filter is used to estimate the recent bitrate (*bps*) and the value is compared to a threshold ($bps < bpsMax$). If the bitrate test passes output is toggled off for *msec* every time *nullMin* null frames are received. The number of null frames received (*nulls*) is also recursively estimated and is reset to zero every time the output is toggled.

Tracking both frames and bitrate independently is probably overkill, but it allows the algorithm to be relatively independent of the channel rate. For example, setting *bpsMax* to a very high value (i.e *FIFO-size * msec_delay*) has the effect of using any channel "dead time" (i.e. strings of null frames) as an opportunity to inject jitter.